

## CMS FPIX Upgrade Cooling Specifications

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These specifications are written for the proposed CO<sub>2</sub> cooling system and associated parts of the detector upgrade. The intention is that these points be discussed and settled before detailed design work is done.

1. Maximum heat load is 15 watts/blade.  
*reason:* Expected heat load with 50% contingency. Heat load is not expected to increase.  
This is for sizing the detector cooling tubes and substrate, not the cooling plant.
2. There will be twelve blades per half-disk.  
*reason:* Blade layout is being developed. The number and size of blades may change, but the total heat load should not.
3. System operates with panel temperature from -20 to +10C.  
*reason:* Allow commissioning without dry gas purge.  
*reason:* Operating at room temperature and full power would require larger tubes.  
*reason:* The existing tubing on the central detector outside PP1 is limited to about 50 bar.  
Operating at 90% of the relief valve settings would put the maximum temperature around 10C.
4. Average temperature stability should be +/- 1C with the detector on.  
*reason:* This is a controls issue. It may be possible to relax this specification and simply control the cooling plant outlet conditions. The control point needs to be defined.
5. Minimum operating temperature with no heat load, i.e. detector on or off, is -30C.  
*reason:* Low coolant temperature permits bigger  $\Delta T$  in substrate.
6. Panel must withstand a sudden change in coolant temperature from 20C to -30C with the panel initially at 20C.  
*reason:* Check thermal contractions between the tube and substrate during rapid cooldown.
7. Cooldown rate must be at least 10C/hour for a complete system cooldown with detectors off.  
*reason:* Cooling system capacity.
8. Coolant temperature decrease from detector inlet to outlet should be less than 8C.  
*reason:* With power variations it is difficult to specify a range of panel temperatures.
9. Maximum ambient temperature is 40C. Refrigerant shall be retained at this temperature.  
*reason:* This is a non-operational condition used to determine the design pressure of the cooling system. If the tubing can not take this pressure, the tubing will dry out when not running and either a refrigerant storage or recharging system will be needed.
10. Design for a depressurization accident with the detector tube initially full of liquid.  
*reason:* Assume that no new liquid would be added. It may be necessary to assume that liquid is added to the tubes depending on the size of the breaks.
11. Normal operation shall be automated so that operations is simply cooling system on/off control and setting the detector temperature.
12. The control system should tie in with CMS or CERN monitoring system.
13. Interlocks must protect the cooling plant and detector against equipment damage.
14. Detector temperature measurements shall be generously applied to cover every thermal concern.
15. Mechanical equipment shall be backed up with spare equipment that starts automatically if the lead equipment fails.  
*reason:* This system is design to have little or no down time due to equipment failure.
16. Equipment and valves in the detector hall shall be minimized.  
*reason:* To allow adjustment or repair without dropping the beam.

17. Equipment, instruments and valves in the detector hall shall be radiation resistant.
18. Equipment, instruments and valves in the detector hall must withstand the fringe magnetic field.
19. Radiation length of the existing blades is 3.64%, of which the cooling channel contributes 1.17%. Radiation length of the upgraded substrate, cooling channel and thermal spreader will be less than 0.6%. See docdb 500 for details.  
*reason:* This is thought to be reasonable based on preliminary calculations.
20. Joints are needed so that half-disk assemblies will be removable for repair. Joints are needed at PP0 and PP1.  
*reason:* The final specification regarding joints must consider ease of repair, mass, material and radiation compatibility and the availability of skilled technicians.
21. Tubing length from PP1 to PP0 is about five meters and follows a tortuous path. Make sure the tube routing with insulation will fit through the limited space. The existing tubing has an 0.472 inch (12 mm) outside diameter.
22. The cooling plant and main transfer lines should deliver 10kW capacity for phase one and be expandable to 20kW for phase two.  
*reason:* These cooling capacities will handle both the barrel and pixel cooling with phase one and the increased intensity of phase two.  
*reason:* There is some feeling that the electronic heat load will decrease for phase two, so 10kW is enough
23. Thermal interference from other cooling or heating systems must be considered.  
*reason:* To re-use the tubing on the central detector outside PP1 may have thermal implications.  
*reason:* This includes thermal effects of BPIX, ambient temperature, AOH, port card, etc.
24. Dielectric breaks must be installed at PP0 between the detector and the piping to PP1.  
*reason:* The leader of detector grounding plans should confirm this.
25. Total refrigerant leak rate should be less than  $1\text{e-}2$  atm-cc/sec.  
*reason:* Based on the modest cost of carbon dioxide and with the intention to avoid the cost of mass spec leak detection.
26. Relevant Design and Fabrication Standards for pressure vessels and piping must be specified.  
*reason:* At Fermilab it would include ASME Section VIII and ASME B31.3. CERN should determine which CE standards are relevant.
27. The design must include corrosion prevention.  
*reason:* This may mean driers to prevent the formation of carbonic acid.